ED&T 7400-4

AEROFEED HYPOCHLORINATOR

SERIES WF

evaluation

U.S. DEPARTMENT of AGRICULTURE FOREST SERVICE
EQUIPMENT DEVELOPMENT CENTER SAN DIMAS, CALIFORNIA

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SERIES WF

EVALUATION

ED&T PROJECT 1546

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TABLE OF CONTENTS

ABSTRACT

Many of the small, low-pressure water systems in areas administered by the Forest Service are not being chlorinated because there have been no known automatic devices which would work on low-pressure water systems. A small device, versatile enough to meet the needs of the many different installations, is needed to automatically chlorinate these water systems.

The Equipment Development Center at San Dimas conducted a series of tests on an Aerofeed Series WF Hypochlorinator, designed by Aerofeed to operate without maintenance for extended periods of time. It requires no outside power source and can operate on water systems with pressures as low as 5 psi.

The Aerofeed Series WF Hypochlorinator appears to have very limited application for Forest Service recreational facilities. It does not perform to manufacturer's specifications under many operating conditions. It may be suitable for certain installations if frequent, careful maintenance is provided by skilled personnel.

INTRODUCTION

During the period of August 8 to 25, 1967, the Equipment Development Center, San Dimas, conducted a series of tests in order to evaluate the Aerofeed Series WF Hypochlorinator (Aerofeed Incorporated - P.O. Box 303, Chalfont, Pa.).

Increased demands are being made on Forest Service recreational facilities. Important among these is the need for safe drinking water systems at widely varying water-usage rates. A number of recreation sites have no electricity and have only low-pressure or gravity water systems.

Chlorination can be accomplished by adding elemental chlorine (Cl_2), hypochlorite of sodium (NaOCl), or hypochlorite of calcium ($CaOCl_2$) to the water. No matter which of these chemicals is used, a reaction with the water takes place; and hypochlorous acid (HOCl) is formed. For the types of water systems in which the Forest Service may have use for this or other chlorinators, it is very seldom that the source is sufficiently remote from the usage point to provide adequate in-line contact time. Generally, therefore, the system must have a reservoir downstream of the chlorinator so that the chlorinated water will be held for an adequate contact time. Sizing of this reservoir is critical, since a lengthy storage period allows the chlorine residual to diminish. A thorough study of the usage rate must, therefore, be made to properly size the holding reservoir.

In 1966, the Center conducted tests on an earlier model of the Aerofeed unit and encountered several problems. The manufacturer then redesigned the chlorinator. The modifications made it desirable to test the improved unit and determine if it was suitable for Forest Service use.

This test was primarily an evaluation of the performance of one unit; however, it gave the operator an opportunity to determine if either the complexity or frequency of necessary maintenance was prohibitive. The test covered the following areas of investigation:

1. Does it dispense chlorine solutions accurately, and may it be relied upon to dispense a constant rate over extended time periods and through many on-off cycles?
2. What flow rates are required to activate the metering device for any given water system?
3. Are the component parts reliable?
4. Can equipment maintenance be performed by average field personnel?
5. How often will maintenance be necessary?

EQUIPMENT

Description

The Aerofeed Series WF Hypochlorinator is a device which is designed to automatically dispense hypochlorite solutions into water systems. It is self-contained and requires no outside power source of any type for water systems with pressures up to about 50 psi. The foot-operated air pump supplied with the unit is capable of

pressurizing the tank to 50 psi. For installations operating at pressures higher than this (up to a maximum of 100 psi), outside power in the form of a compressor or a pressurized gas container is necessary. Because the chlorinator is basically a dispensing device, the water flow rate must be known so that the chlorine-metering unit can be adjusted to maintain the proper chlorine residual. Although the unit is a constant feed rate device, it is turned on and off by a differential pressure created by water system use; i.e., water flow is required to open the metering valve.

Components

The 1967 model chlorinator is shown in figure 1. The major component parts are numbered and their functions are briefly described following the photograph. The

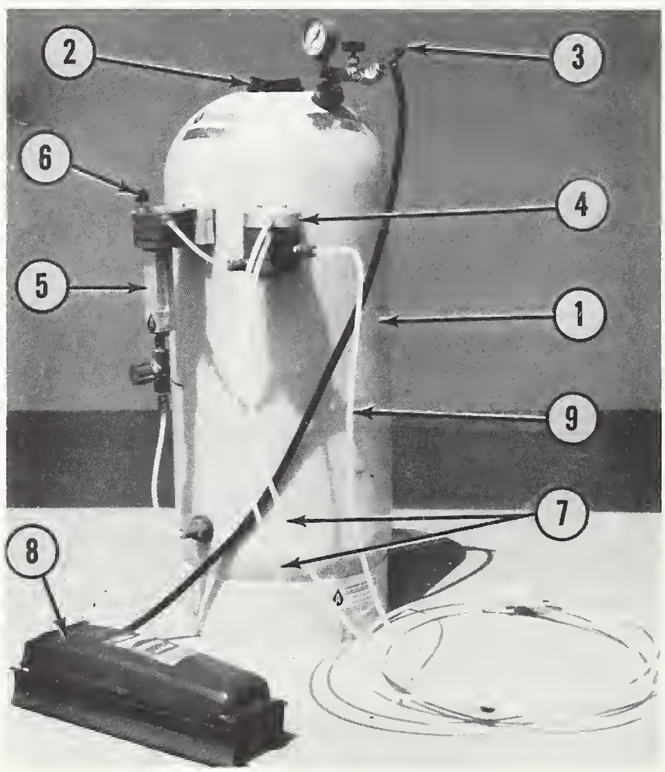


Figure 1. 1967 Aerofeed Series WF Hypochlorinator

1. Tank - A 15-gallon fiberglass pressure vessel which holds the chlorine solution and pressurized air to force the solution into the water system (100 psi rated working pressure).
2. Fill cap - Port for charging the tank with solution.
3. Pressurizing port - Port for charging the tank with air pressure. (This has a gauge for monitoring pressure and a valve for sealing the tank after it is pressurized.)
4. "VDU" - Automatic on-off valve controlled by differential pressure in the water system.

5. Flow meter - A meter which indicates the chlorine flow rate in percent.
6. Flow regulator - A needle valve through which the flow of chlorine can be adjusted.
7. VDU sensing lines - Plumbing connected between the VDU and the water system for sensing differential pressures across a restriction.
8. Air pump - A foot-operated pump used to pressurize the tank.

   Filter - Removes minute particles in the solution to minimize blockage of components in the controls. This is not seen in the photo, as it is located on the bottom interior of the tank.
9. Dispensing line to water system.

differences between this series WF Hypochlorinator and the previous model are not readily apparent, as most of them involve changes to parts inside the major components. At the time of the testing, the price of a complete Series WF Hypochlorinator (including a foot pump) was approximately $400.00, not including shipping charges and possible discounts.

<u>Operation</u>

The theory behind the operation of the chlorinator is quite simple. A tank containing a hypochlorite solution under air pressure is connected to the water system.

The solution will flow from the tank into the water system as long as the tank pressure is greater than the pressure in the water system. Between the tank and the water system, a needle valve (flow rate valve) is placed in the discharge line so that the solution flow rate can be regulated.

The chlorinator has a device for initiating and halting the flow of chlorine. This unit - the "VDU" - is located in the solution discharge line between the flow rate valve and the water system. The VDU opens the discharge line when it senses a differential pressure and closes the line when there is no differential pressure. Two sensing lines must be connected between the VDU and the water system. They must be installed in the water system in such a way that a pressure drop occurs between them when there is a flow, thereby applying a differential pressure to the VDU. This condition can be met by the use of a globe or gate valve to create the restriction. The differential pressure causes a diaphragm in the VDU to deflect. This, in turn, causes a spring-loaded ball valve to open, allowing the chlorine solution to flow.

TEST DESCRIPTION

Phase I - VDU Operating Characteristics

In order to obtain the data required in this phase of the test, it was necessary to design and assemble a test stand. Instrumentation for monitoring the differential pressure and also the pressures at significant points in the water system was included in the test stand. A means of applying a differential pressure to the VDU and the capability of adjusting the differential over a wide range at varying system pressures

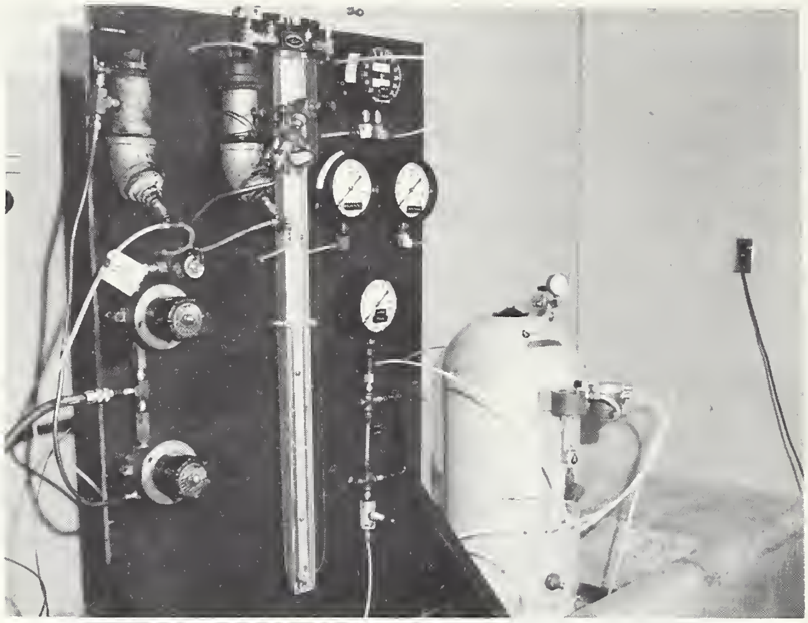


Figure 2. Aerofeed chlorinator connected to test stand

were also needed. To provide the greatest versatility, compressed air from the laboratory system was routed through pressure regulators to reservoirs and finally to the VDU. A diagram of the complete test apparatus is included in the appendix of this report (figure 5). The reservoirs were partially filled with water so that the discharge lines would apply pressurized water to the VDU. Two identical systems of regulators and reservoirs were used, and each was connected to one of the differential sensing lines on the VDU.

The independent adjustment allowed an accurate simulation of water system pressures, including lower stream pressure due to losses through a pipe restriction. Six test situations were studied. In each case the tank was charged with 4 gallons of hypochlorite solution. After all parameters of a particular situation were set, the pressure on the upstream (high-pressure) side of the VDU was increased in increments of approximately 1 inch of mercury. This was continued until the valve opened. A 30-second waiting period after each change in differential pressure was required to insure that no delaying aspects of any of the controls would introduce errors. After the valve opened, the procedure of increasing the differential was continued until it was at least 5 inches of mercury greater than when the valve opened. At the point where the valve opened and for each incremental increase following, the differential pressure was recorded, along with the indicated flow rate and simulated downstream water system pressure. The procedure was then reversed to monitor flow rate at decreasing differential pressures until the valve closed. The different situations for which this procedure was followed were:

1. 1% chlorine solution
   95 psi tank pressure
   80 psi water pressure

2. 1% chlorine solution
   33 psi tank pressure
   15 psi water pressure

3. 1% chlorine solution
   20 psi tank pressure
   5 psi water pressure

4. 16% chlorine solution
   95 psi tank pressure
   80 psi water pressure

5. 16% chlorine solution
   33 psi tank pressure
   15 psi water pressure

6. 16% chlorine solution
   20 psi tank pressure
   5 psi water pressure

Phase II - Reliability and Repeatability Test

The second phase of this test consisted of applying three different situations to the chlorinator and cycling the chlorine flow - on, 40 seconds; off, 20 seconds - for 24 hours for each situation. The tank pressure and quantity of solution were recorded at both the beginning and end of the test. Other data which were recorded at selected time intervals were: date, time, indicated flow rate, measured flow rate, tank pressure, water system pressure, and differential pressure. The situations for which this test was performed were:

1. 4 gallons of 1% chlorine solution
   20 psi tank pressure
   5 psi water pressure
   5 to 6 cc's per minute solution flow rate
   4 inches of mercury differential pressure

2. 4 gallons of 16% chlorine solution
   33 psi tank pressure
   15 psi water pressure
   1 to 2 cc's per minute solution flow rate
   4 inches of mercury differential pressure

3. 7 gallons of 16% chlorine solution
   95 psi tank pressure
   80 psi water pressure
   10 to 12 cc's per minute solution flow rate
   5 to 6 inches of mercury differential pressure

It was necessary to add to the test apparatus in order to cause the chlorine flow to cycle. To simulate field conditions, this was accomplished by cycling the differential pressure from 0 to the required level without changing the simulated upstream water-system pressure. Timer-controlled solenoid valves were used to cycle the differential pressure. Throughout these cycling tests, flow rate measurements were taken approximately every 2 hours. First the cycling was halted and the solution flow rate was allowed to become constant. Then the flow was measured over 2-minute time periods several times to insure that steady-state conditions had been achieved.

Phase III - Effect of Varying Internal Tank Pressures

The final phase of this test was planned to determine what effects reducing tank pressure has on solution flow rate when the water system pressure is held constant. Water system pressure was maintained at 50 psi, and a differential pressure was set

so that chlorine flow was initiated. The tank was charged with 4 gallons of 1-percent chlorine solution and pressurized to 95 psi. The chlorine flow was then set at 6 cc's per minute and allowed to stabilize. Tank pressure was then decreased in increments of 10 psi until a tank pressure of 65 psi was reached. At this point the increments were reduced to 2 psi, and the process was continued until pressures reached equilibrium. After each incremental decrease in tank pressure, the water system pressure, differential pressure, indicated solution flow, and actual solution flow were recorded.

No physical change in the test apparatus was necessary for this phase; however, the timers were disconnected.

TEST RESULTS

Data taken during Phase I of the test show several significant characteristics of the Aerofeed unit. First, the chlorine discharge rate is not a function of pipeline differential pressure for practical considerations. Table 1 in the appendix is a presentation of data taken during a typical test run. For all six situations the valve opened completely and abruptly. The valve closed in the same fashion for five of the six runs. One of the six test runs did show a 10-percent decrease in indicated flow just prior to complete closing of the valve. No explanation has been found for this single deviation. Secondly, valve opening generally occurs at 4 inches of mercury (54.2 inches of water) differential, with some scattering of data at very high tank pressure. The test procedure included varying the VDU adjusting mechanism until it would close at 0 differential pressure. The valve closes at a differential pressure slightly below that at which it opened. Table 2 in the appendix gives the opening and closing points for the different situations.

The chlorinator did not function well during two of the three cycling tests in Phase II, and therefore only the data from the good test run are presented in tabular form (see table 3 in the appendix). All three tests, however, are explained more thoroughly in the discussion.

Phase III progressed smoothly, and the data show that tank pressure does affect the solution flow rate. This effect is not as great as was expected. A tank pressure 2 psi greater than the water system pressure produced a flow only 25 percent below that which was produced by a tank pressure of 45 psi above the system pressure. Graph 1, in the appendix, presents the data recorded during this phase.

DISCUSSION

Close examination of the design of the VDU yields an explanation for its opening and closing characteristics. Its operation was described in preceding sections of this report, but a sketch is presented here to aid in the explanation.

From the sketch it can be seen that the available area between the plunger and the flow orifice is very small. It can be further seen that only a very minor movement of the ball is required to open an equal area at the end of the orifice, thus allowing full flow.

Information published by Aerofeed Inc., indicates that a maximum differential pressure of 20 inches of water is required to activate the VDU. Test data show that VDU opening occurs generally at 54.2 inches of water. (These results are very similar to those obtained during the 1966 tests.) This is probably due to manufacturing tolerances which cause variations in diaphragm and spring force constants. Table 4, in the appendix, relates differential pressure to flow rate across globe and gate valves in different sizes.

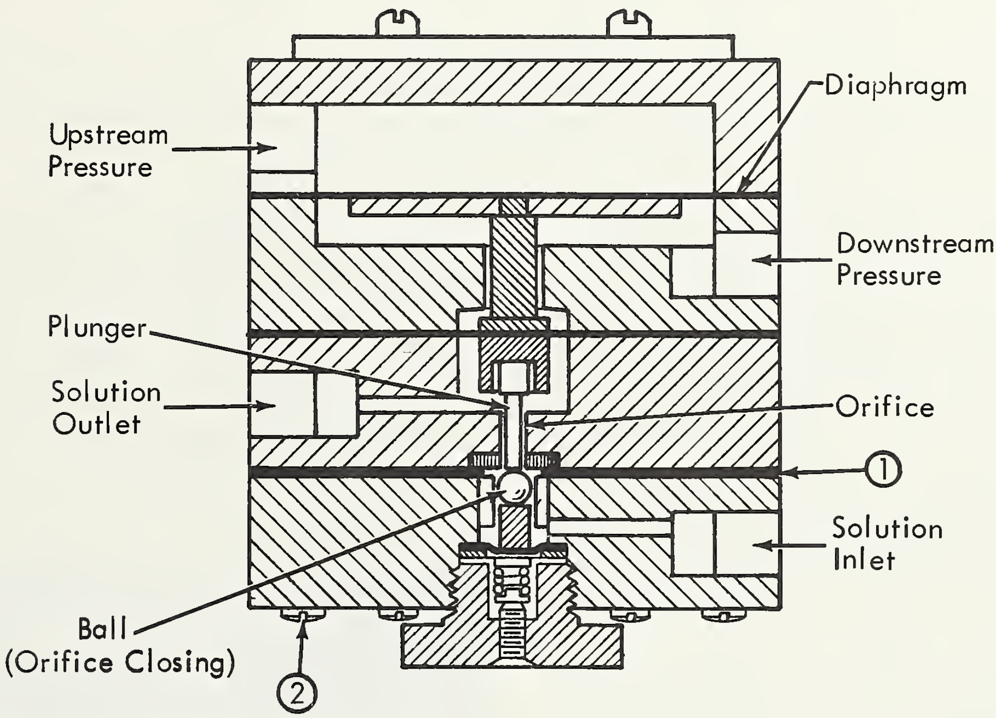


Figure 3. Cross section of VDU unit with ball valve in open position

The reason for the difference between the VDU opening and closing differentials appears to be as follows: when opening of the valve is imminent, only one important force - from the plunger due to the deflected diaphragm - is acting on the ball in opposition to the spring. When chlorine solution is flowing, one significant difference is due to the velocity head of the fluid. Other forces arise from internal friction of the components (three diaphragms, spring, and related linkage). These forces are equivalent to the difference in the differential pressures for opening and closing of the valve.

One further characteristic was noted. When the differential pressure is applied abruptly, the ball on the flow meter rises quickly to a point higher than the set level (usually to the limit of travel) and then drops slowly to the set level. This is normal and is not sufficiently important to warrant the complex explanation which is necessary.

The cycling test which was conducted with a 16-percent chlorine solution and a 1- to 2-cubic-centimeter-per-minute solution flow rate showed that the chlorinator would not function precisely as advertised. While the manufacturer's literature states that performance at these conditions is lower than at medium flows and concentrations, this test showed that the chlorinator would not be suitable for installations when operating with the 16-percent solution. Maintenance was the principal problem. The low flows allowed deposits or films to form on component parts of the chlorinator. This resulted in complete blockage of the flow rate valve at one time and required adjustment of this valve several times because of partial blockage. Another result was that a film formed on either the meter tube or the meter ball, or both, thus giving erroneous readings. These could mislead the operator by giving a false indication of the unit's dispensing rate. At times the ball stuck (tapping the meter slightly would sometimes free the ball). When the chlorinator is used under these or similar conditions, the flow rate valve and flow meter must be cleaned frequently to keep the chlorinator operating properly. The test showed that the chlorinator should be checked each day for maintenance.

Several problems were also encountered when the chlorinator was set to discharge 11 to 12 cc's per minute of a 16-percent solution into a water pressure of 80 psi. The problems appeared to be due to the high pressures (95 psi tank pressure). Early in this test leaks developed in the VDU, flow rate assembly, and tank. Water leaked from the VDU in the area indicated by "1" on figure 3. (Only chlorine solution should be in that area of the VDU.) Close examination of the unit showed that the screws (indicated by "2" on figure 3) pass completely through the lower three major sections and are threaded into the uppermost sections, holding the VDU together in a sandwich-type structure. The water was leaking into the screw hole at one of the upper diaphragms and passing down the hole and out of the unit at the weakest point. It was found that one of the screws had only one to two threads extending into the upper section. It was replaced with a slightly longer screw and tightened securely. This eliminated the leakage, and testing was continued.

The chlorinator was checked early the following morning, after having been allowed to run all night. A leak had developed in the flow rate assembly during the night, causing corrosion and extensive buildup of chloride deposits on the unit (see figure 4). Blockage of the flow rate valve had also occurred, as shown by the indicated flow rate being zero. A thorough cleaning of many of the chlorinator's component parts (several hours' labor) was required to return the chlorinator to service.

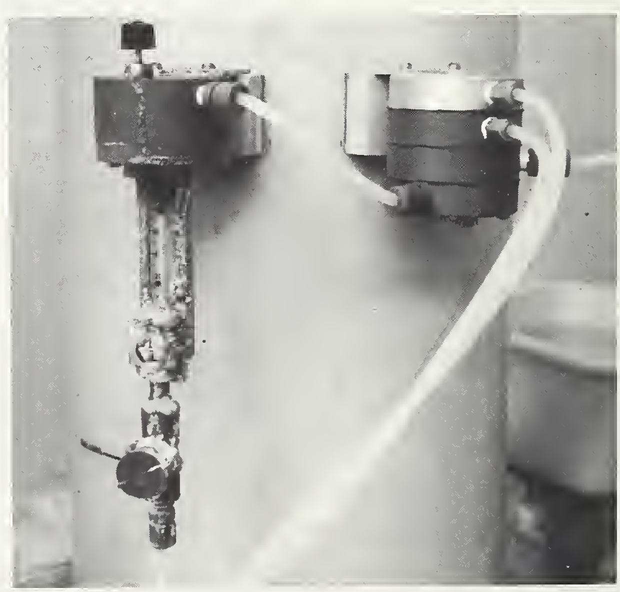


Figure 4. Corrosion & chloride deposits on flow rate assembly

The leak in this unit was found to be around a screw. Six bottom-entering screws hold the flow rate assembly together in a sandwich-type structure. Two of these screws are shorter than the other four. This allows the two top-entering screws which are used to mount the unit to the chlorinator tank to be threaded into the same holes. One of these screws was replaced with a screw which was slightly longer, and the leak was stopped (only one screw held the flow rate unit onto the tank).

After the chlorinator had been shut off for one night during this section of the test, it was found that the tank pressure had dropped 5 psi overnight. This indicates that the tank has a high-pressure air leak, most probably around the fill cap or the pressurizing port.

The only cycling test for which the chlorinator functioned reliably was the one where the flow rate was set at a medium flow of 5 to 6 cc's per minute, the chlorine concentration was weak (1 percent), and water and tank pressures were low (15 and 33 psi, respectively.). However, the solution flow rate did decrease from the set rate during this test, as shown by the data (see table 3 in the Appendix). The manufacturer's publications state that a drop in flow rate of 8 to 10 percent of the full-scale reading of the flow meter is normal over a 1- to 2-day period following recharging of the system. The drop in flow seen during this test totals nine percentage points on the flow meter scale and therefore can be considered normal. Although this drop is considered normal by the manufacturer, it is very undesirable from a safety viewpoint, since actual chlorine residual can be reduced greatly from the desired level. These nine percentage points were equal to a 45-percent drop in solution flow rate from the original setting of 5 to 6 cc's per minute.

The foot pump was evaluated during the testing of the 1966 Series WF Hypochlorinator. It was found that the maximum practical pressure obtainable, using this pump, was 50 psi. When the tank was charged with 6 gallons of solution, 12 minutes of pumping (742 strokes) were required to pressurize the tank to 50 psi.

CONCLUSIONS

1. Under average operating conditions, the flow rate decreases below the set value after the unit has been in operation for several hours. However, after this stabilization period the chlorinator does dispense chlorine solutions accurately.
2. Flow rates of 12.7 gpm for a 1-inch fully open globe valve or 28.6 gpm for a $1\frac{1}{2}$ inch size are required to open the VDU. These are the flows which are required to develop 4 inches of mercury differential pressure in the system.
3. Component parts are not reliable under all usage conditions. The flow rate needle valve and sight gauge do not function properly when high concentrations of chlorine are handled. The tank, the VDU, and the flow rate assembly developed leaks at high tank and water system pressures.
4. Most maintenance, with the exception of the VDU unit, can be performed by average field personnel. The cleaning of the VDU assembly should be reserved for careful, interested personnel with a high mechanical aptitude. Maintenance of the VDU unit by unskilled personnel <u>is not</u> recommended.

5. Under some operating conditions maintenance will be prohibitively frequent. When high concentrations of chlorine are used, particularly if the set solution flow rate is low, daily inspections (possibly daily cleaning of the flow rate assembly) will be required.

The chlorinator tested did not perform as stated by the manufacturer for many situations within the recommended ranges of conditions. Because of the limited ranges of tank pressures and solution flow rates at which the device performs without frequent maintenance, it would have limited application for Forest Service use. Because of the intricacy of the device, field maintenance may be difficult.

RECOMMENDATIONS

The Aerofeed unit, like other units, should be installed and relied upon for the treatment of a water system only after a thorough study has been made by a qualified engineer and he has recommended its use. Before installations, operational limitations for each particular site should be examined. As an example, two systems were worked out below to show the difference in the number of gallons of water that can be treated and the length of time between servicing, due only to different water system pressures and their effect on the permitted solution volume in the tank.

System #1	System #2
5 psi water pressure	45 psi water pressure
10 gallons of solution*	2 gallons of solution*
20 gpm average water flow	20 gpm average water flow
20% stock chlorine solution	20% stock chlorine solution
6.0 cc/min. dispensing rate 1/	6.0 cc/min. dispensing rate 1/
1 ppm chlorine yield	1 ppm chlorine yield
60 psi tank pressure (foot pump)	60 psi tank pressure (foot pump)
105 hours 2/ between servicing**	21 hours 2/ between servicing**
126,000 gals. 3/ of treated water	25,200 gals. 3/ of treated water

*Indicated allowable solution volume shown in Table 1 of the Aerofeed Chemical Dispenser Instruction Manual #1B-TD-965-2.

**Time is based on continuous flow. Any non-use periods would extend this time.

If the tanks in the above systems could be pressurized by an air cylinder equipped with a pressure regulator, each tank could be filled with 10 gallons of solution. Then the service interval and gallons of water treated would be equal for both systems (105 hours and 126,000 gallons).

It is further recommended that the Aerofeed unit may be considered for chlorination of Forest Service water systems only where conscientious, skilled maintenance can be provided.

1/ From Aerofeed Publication HC-1A, Table B-4 2/ From Aerofeed Manual #1B-TD-965-2, Table I 3/ From Aerofeed Manual #1B-TD-965-2, Table IIB

APPENDIX

TABLE 1. VDU opening and closing characteristics

Differential Pressure Inches of HG	Differential Pressure PSI	Increasing or Decreasing	Solution Flow Rate Percent	Water Pressure PSI
0	0	Increasing	0	5
1	0.5		0	5
2	1.0		0	5
3	1.5		0	5
4	2.0		20	5
5	2.5		20	5
6	2.8		20	5
7	3.2		20	5
8	3.8		20	5
14	6.5	Increasing	20	5
8	3.8	Decreasing	20	5
7	3.5		20	5
6	3.0		20	5
5	2.5		20	5
4	2.0		20	5
3	1.5		20	5
2	1.0		20	5
1	0.5		0	5
0	0	Decreasing	0	5

1 Percent Chlorine Concentration
20 PSI Initial Tank Pressure
19 PSI Final Tank Pressure

Note: See Table 4 for Differential Pressure Equivalencies.

TABLE 2. VDU opening and closing points

Tank Pressure PSI	Water Pressure PSI	Solution Concentration Percent	Opening Differential Inches of Mercury	Closing Differential Inches of Mercury	Set Solution Flow Rate Percent
20	5	1	4	2	20
33	15	1	4	2	20
95	80	1	2	1	20
20	5	16	4	1	50
33	15	16	3	0	50
95	80	16	5	1	79

TABLE 3. Cycling test data

Date and Time	Tank Pressure PSI	Solution Flow Rate cc's/Minute	Water Pressure PSI	Differential Pressure Inches of Mercury	Indicated Flow Rate Percent
8/17/67 1000 hrs	20	6	5	4	20
8/17/67 1100 hrs	20	5	5	4	17
8/17/67 1300 hrs	20	4	5	4	13
8/17/67 1400 hrs	20	3.5	5	4	12
8/17/67 1500 hrs	20	3.5	5	4	12
8/17/67 1600 hrs	20	3.5	5	4	11
8/18/67 0830 hrs	18	3.5	5	4	11
8/18/67 1030 hrs	18	3.5	5	4	11

1 percent chlorine concentration
4.0 gallons initial solution volume
2.88 gallons final solution volume
5 to 6 cc's/minute initial flow rate valve setting

TABLE 4. Correlation between differential pressure and flow rate for equivalent pressure drop across certain pipeline restrictions

Differential Pressure Inches of Mercury	Flow Across Globe Valve in GPM	
	1-inch	1-1/2 inch
1	6.3	14.3
2	9.0	20.2
3	11.0	24.7
4	12.7	28.6
5		31.9

Notes:

1. The flow rates shown are for a fully open globe valve.
2. A fully open gate valve would require flows approximately 50 times as great to produce equivalent pressure drops.
3. Pressure drops to produce equivalent flows could be achieved by using a gate valve approximately two-thirds closed.
4. Partially closing a globe valve would produce equal pressure drops at lower flow rates.

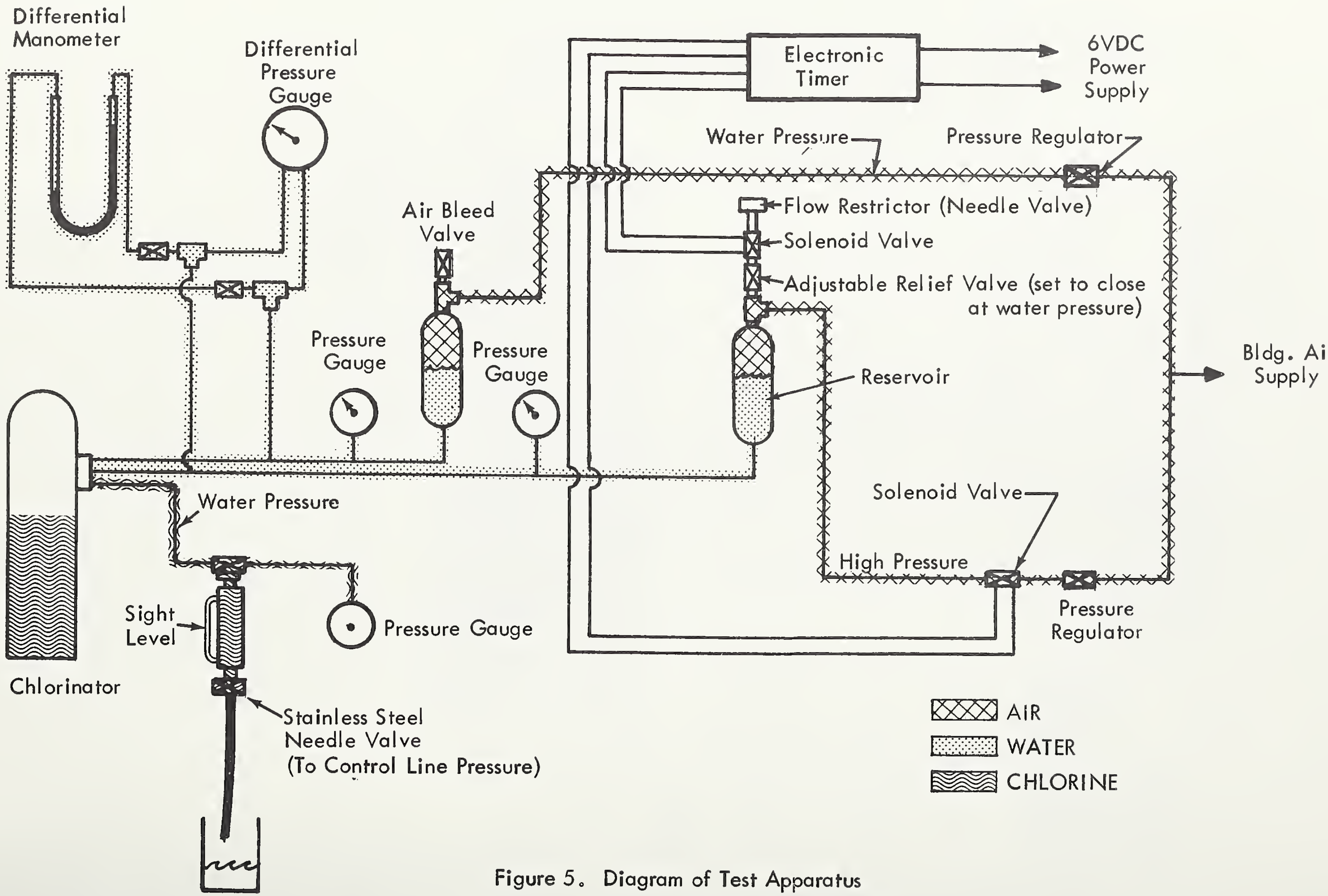
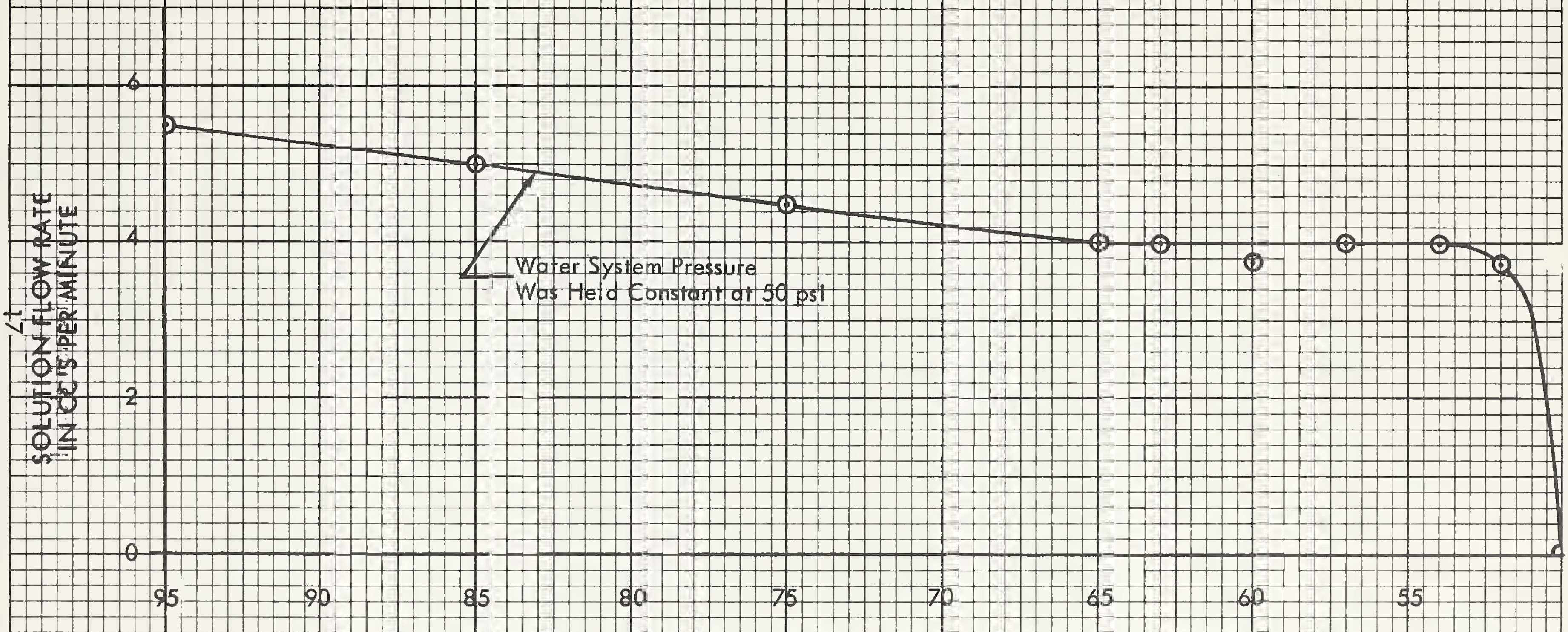


Figure 5. Diagram of Test Apparatus



Graph 1
SOLUTION FLOW RATE
WITH REDUCING TANK PRESSURE

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December 1, 1967

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